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RESPONSE DISTANCE OF FERRUGINOUS PYGMY-OWLS TO BROADCASTED CONSPECIFIC CALLS

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Abstract.—To assess the efficiency of broadcast surveys for Ferruginous Pygmy-Owls (*Glaucidium brasilianum*), we tested the response distance of nine, radio-tagged, adult males. We recorded vocalization and movement toward the broadcast station as separate types of responses. Response to broadcasted conspecific calls was tested for each pygmy-owl at distances from 250–700 m. Broadcasted calls elicited vocal response from all nine pygmy-owls tested at ≤550 m and eight of the nine pygmy-owls moved toward the broadcast station. At 600 m, eight responded vocally and seven of the nine pygmy-owls tested, moved toward the broadcast station. Of the six pygmy-owls tested at 700 m, four responded vocally and three moved toward the broadcast station. As we recorded a 100% response from a distance of ≤550 m, the effective coverage of areas formed by establishing survey points from 400–1400 m apart, in 100 m increments, would range from 97.7–61.7%, respectively. For these same increments, broadcast overlap would range from 54.7–0.0%, respectively. Based on response distance information, researchers may choose between different survey levels. For example, to maximize detection, researchers may develop survey protocols that canvas an area with overlapping radii and redundant sampling. Antithetically, to determine general distribution of a species over expansive areas, researchers may choose to increase survey efficiency by reducing broadcast overlap, survey effectiveness, and redundant sampling.

Key Words: *Ferruginous Pygmy-Owl;* Glacidium brasilianum; *broadcast survey.*

Distancia de respuesta de *Glacidium brasilianum,* a vocalizaciones emitidas de la misma especie

Resumen.—Para evaluar la eficiencia de muestreos a través de difusión de llamados para *Glaucidium brasilianum,* probamos la distancia a la que respondieron nueve machos adultos con radio telemetría. Definimos vocalizacion y movimiento hacia la estacion de difusión como dos respuestas distintas. Respuestas a llamados grabados de la misma especie se probaron a distancias de 250–700 m. Los llamados difundidos causaron respuesta vocal en los nueve tecolotitos probados a <550 m; ocho de los nueve tecolotitos probados a 550 m respondieron con vocalizacion, se movieron hacia la estacion de difusión. A 600 m, ocho de los nueve probados respondiernon vocalmente y siete de los nueve respondieron vocalmente y se movieron hacia la estacion de difusión. De seis tecolotitos probados a 700 m, cuatro respondieron vocalmente y tres se movieron hacia la estacion de difusión. Ya que obtuvimos una respuesta del 100% a una distancia de 550 m, la cobertura efectiva de areas formadas al establecer puntos de difusión de 400–1400 m, en incrementos de 100 m, cubririan entre el 97.7–61.7%, respectivamente. Para los mismos incrementos el area de traslape de areas de difusión efectiva cubririan entre el 54.7–0.0%, respectivamente. Al utilizar la información de distancia de respuesta investigadores podrian escoger entre diferentes niveles de muestreo. Por ejemplo, para maximizar la deteccion de especies de interes, un investigador podria desarrollar protocolos que cubran toda el area con traslape de areas de difusión y hacer muestreo redundante. Sin embargo para determinar la distribución general de una especie sobre areas extensas, un investigador podria decidir en protocolos de muestreo que incremente la eficacia de cobertura al reducir el traslape en el area efectiva de cobertura del area de difusión

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Accurate survey methods are critical to the management and conservation of threatened and endangered species. Survey methods can provide estimates of distribution, relative abundance, habitat use, and with some species, sex ratios. These baseline data are important for evaluating the status and trends of species impacted by changing land-use practices and loss of suitable habitat. Measuring response of individuals to broadcasted conspecific calls is an important method employed for surveying avian populations (Allaire and Landrum 1975, Johnson et al. 1981, Smith et al. 1987, Stahlecker and Rawinski 1990). However, without definitive unbiased information regarding effective sampling area, broadcast surveys only provide an index of presence/absence (McLeod and Anderson 1998). The overall effectiveness of this method depends on several factors. First, responsiveness varies among species and seasonally within species (Springer 1969, McNicholl 1978). Second, terrain and other environmental factors (e.g., wind and precipitation) affects dissipation of sound waves and, thus, influences the maximum distance from which a response can be elicited (DeMaso et al. 1992) and answering calls can be heard. Third, the distance between sample points determines the degree of overlap among broadcast radii. Hence, the distance between sample points influences the potential for redundant sampling to occur, such that if the distance between sites is too small, individuals can be counted multiple times, providing over-estimates of abundance or population size.

In the United States, the Ferruginous Pygmy-Owl (*Glaucidium brasilianum*) only occurs in southern Texas and southwestern Arizona. In Arizona, it is currently listed by the U.S. Fish and Wildlife Service (1997) as endangered. This species is a cavity nester that requires mature trees, including large columnar cacti for nesting, and an adequate prey base (Proudfoot and Johnson 2000). Throughout Arizona and Texas, pygmy-owl populations are fragmented by islands of suitable habitat (Oberholser 1974, Millsap and Johnson 1988, Proudfoot and Johnson 2000). The determination of population sizes and distributions are essential data for assessing population viability and the identification of critical habitat. As a case in point, information from broadcast surveys used to estimate density and distribution of pygmy-owls in Texas suggest a viable population occurs in Kenedy County (Wauer et al. 1993, Mays 1996). Information provided from these surveys was undoubtedly a key factor in the final decision of the Service not to list the pygmy-owl as threatened in Texas (U.S. Fish and Wildlife Service 1997). These survey data were collected and interpreted without information on the territory size of this species and the distance at which pygmy-owls would respond to broadcasted conspecific calls. Hence, the frequent clustering of responses that occurred within the live oak-honey mesquite (*Quercus virginiana-Prosopis glandulosa*) forest (Wauer et al. 1993, Mays 1996) may have been the result of redundant sampling of individuals. Mays (1996) established broadcast stations 400 m apart along road transects in the initial survey and used a 400 m minimum to determine random placement of broadcast stations during her repeated survey effort. Wauer et al. (1993: 1072) used modified Emlen (1977) method and U.S. Fish and Wildlife Service Breeding Bird Survey method to conduct broadcast surveys. He provided no specific information about how the two methods were employed (e.g., distance between broadcast stations). Information obtained during a pilot study to ascertain the response distance of pygmy-owls (i.e., two radio-tagged pygmy-owls were recorded responding at 600 m from the broadcast station) prompted Mays (1996) to urge caution be used when interpreting survey data collected along transects with survey points established ≤400 m apart.

In January 2000, the U.S. Fish and Wildlife Service (2000) issued a standard protocol to be used for surveying areas that were proposed for future development within boundaries designated as critical habitat for pygmy-owls in Arizona. Although the protocol was based on data provided in the available literature and from information submitted by scientists and non-scientists during the public-comment period, the U.S. Fish and Wildlife Service (2000) did not support the protocol with research results or information documenting effectiveness. Hence, as was the case with Wauer et al. (1993) and Mays (1996), the survey protocol currently employed in Arizona may provide a biased measurement of pygmy-owl abundance. The objective of this paper was to provide information regarding the response distance, vocal and movement, of pygmy-owls to broadcast conspecific calls. We suggest that this information be used in the development of survey protocols that assess pygmy-owl distribution and long-term population trends accurately.

STUDY AREA AND METHODS

Research was conducted within 29 000 ha of live oak-honey mesquite forest in Kenedy County, Texas, the same forest in which Wauer et al. (1993) and Mays (1996) conducted surveys to estimate population numbers for pygmy-owls in Texas. Climate was subtropical with 68 cm and 24°C of mean annual precipitation and temperature, respectively Elevation of the study area ranged from 5–21 m.

Nine adult male pygmy-owls (four in 1995 and five in 1996) were trapped during the nesting season (April and May; Proudfoot and Johnson 2000), fitted with transmitters, and monitored for 7–10 d prior to testing. Because spontaneous calling (bouts) of pygmy-owls are usually crepuscular (Gilman 1909, Proudfoot and Johnson 2000), testing was restricted to 30 min before and after sunset, as determined by the U.S. Naval Observatory, Washington, DC U.S.A. (http://mach.usno.navy.mil/cgi-bin/aa_rstablew.pl). Testing was not conducted when winds exceeded 24 kph or when precipitation occurred (Proudfoot and Beasom 1996).

Our testing was limited to ≤700 m, because when establishing the protocol for conducting call count surveys for Northern Bobwhites (*Colinus virginianus*), DeMaso et al (1992) determined 700 m was the apex for surveyors to detect calls at 60–70 decibels (db), a similar acoustical level as produced by pygmy-owls. Two male pygmy-owls elicited by researcher's vocal mimic of the pygmy-owl's territorial call were recorded at 66–78 db (Proudfoot and Johnson 2000).

Using 3-element Yagi antennas and portable radio-receivers, two researchers tracked a radio-tagged pygmy-owl until obtaining visual contact. One researcher (R1) visually and electronically monitored the pygmy-owl while another researcher (R2) used compass bearings and pacing (Stoddard and Stoddard 1987) to establish a broadcast station at the distance desired for testing (e.g., 500 m). Researchers maintained contact via 2-way radio. If the pygmy-owl moved while R2 was locating the broadcast station, R1 relayed its new location to R2, and adjustments (repositioning of broadcast station) were made to maintain the distance desired for testing (e.g., 500 m). A portable recorder capable of producing 95–105 db at a distance of 1 m from the speaker was used by R2 to broadcast conspecific calls, recorded locally, toward the targeted individual. This equipment met output recommendations for raptor broadcast surveys (Fuller and Mosher 1987).

While at a station, broadcasting continued for 3 min, during which time any pygmy-owl movement or vocalization was recorded. The characteristic call of pygmy-owls is a simple series of interrupted single notes, hence, continued broadcast should not have hampered detectability (Proudfoot and Beasom 1996). To eliminate errors that would result from recording responses from non-targeted individuals, R1 maintained direct observation of test subjects during the initial stages of testing, radio-telemetry was used to monitor movement of radio-tagged individuals that responded during testing, and R2 located responding individuals that moved toward the broadcast station and verified identification of the test subject with radiotelemetry.

Clearly, any reduction in the distance between the broadcast station and the target individual would result in a measurable difference in decibels received at the target's location. Thus, to test the response distance in a reasonable manner, the distance between broadcast stations should be far enough to result in a significant change in sound reception by the targeted individual. In 1995, testing began at 400 m and increased daily by 100 m increments to 700 m; each individual was tested once daily (Kennedy and Stahlecker 1993). In 1996, sampling was reversed and began at 700 m; if no response was recorded the broadcast station was moved 50 m closer and testing was continued. At each new distance interval a 5-min adjustment period (silence) was observed before broadcasting was resumed. Because we invoked a 5-min adjustment period and visually monitored each individual during testing, we were confident that the response distance recorded was the distance at which the response was elicited. This protocol (5-min of silence followed by 3-min of broadcasting) was repeated until vocal response and movement toward the broadcast station was recorded. In 1996, we selected the distance (50 m) between broadcast stations based on the time available to conduct tests. Because birds establish territories and maintain and defend areas based on energetic budgets and physical restrictions, confronting conspecifics outside territorial boundaries may be counterproductive. Hence, birds with established territories make response decisions based on assumed location of conspecific and inferred threat (Brown 1969). Therefore, the sample protocol used during 1996 may simulate natural events and behavior.

Pythagorean and Archimedes theorems were used to describe broadcast coverage based on pygmy-owl response distance information. Theoretical models were used to estimate sampling coverage with regard to effective broadcast radii and spacing of survey points (Fig. 1). For example, with an effective broadcast radius of 550 m, surveyors would essentially sample 94.8% of the rectangular area formed from multiplying the distance between survey points (600 m) by the diameter (1100 m) of the broadcast circle. With this sample effort, 34.2% broadcast overlap would occur. If survey points are established 1100 m apart, 78.5% of the described area would be sampled, with 0.0% broadcast overlap (Fig. 1).

RESULTS

In 1995, all four pygmy-owls tested at 400 and 500 m responded vocally, moved toward the broadcast station, and continued to vocalize. At 600 m, three pygmy-owls responded vocally, moved toward the broadcast station, and continued to vocalize; the fourth only responded vocally. Due to time constraints, only one pygmy-owl was tested at 700 m in 1995. It too responded vocally, moved toward the broadcast station, and continued to vocalize.

In 1996, two of five pygmy-owls tested at 700 m vocalized, moved toward the broadcast station, and continued to vocalize. A third pygmy-owl responded vocally at 700 m, moved (<100 m) toward the broadcast station and continued to vocalize at 600 m. The fourth pygmy-owl responded vocally at 600

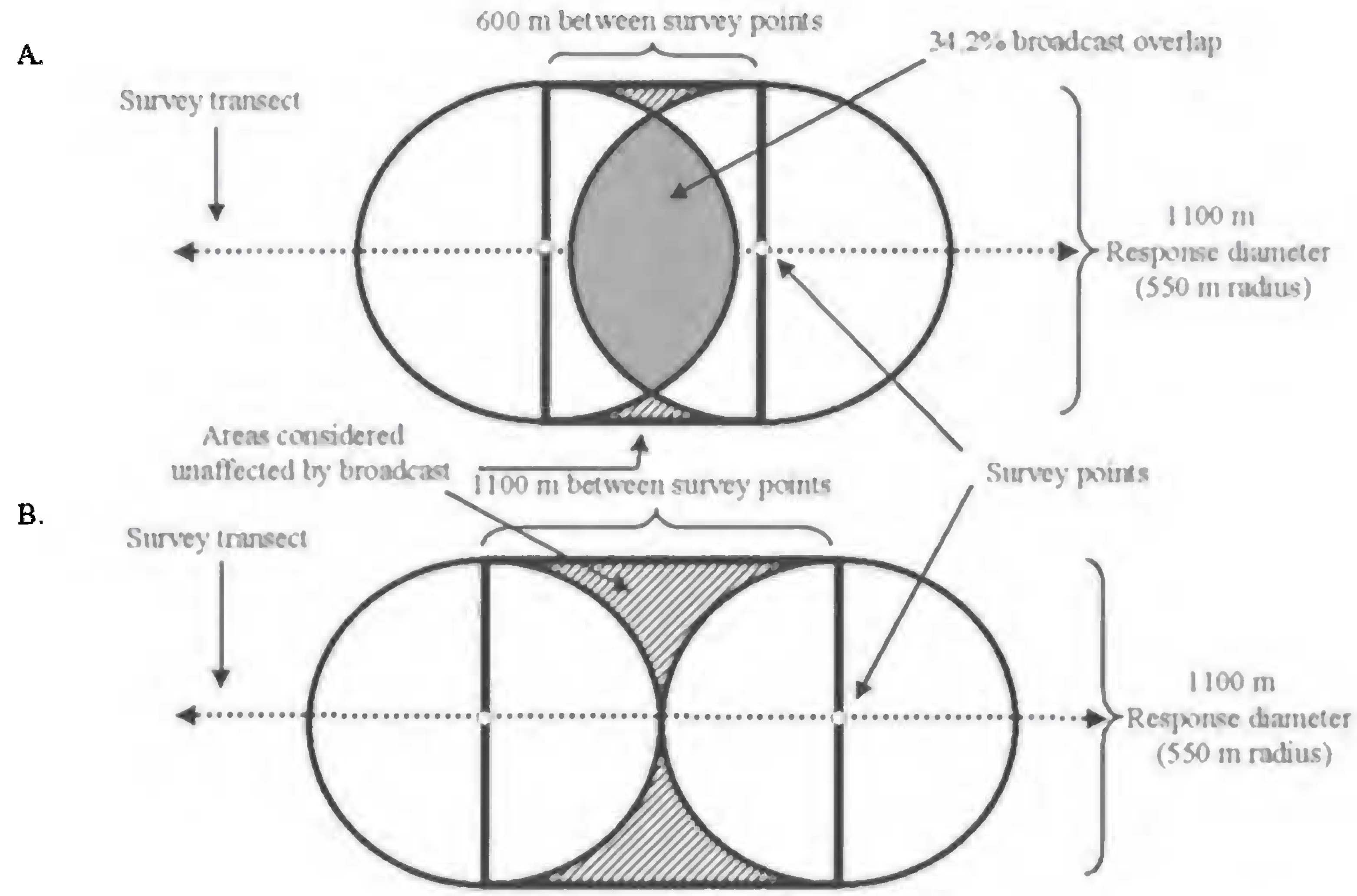

Figure 1. Schematic rendition of area surveyed along transects with broadcast points established 600 m (A) and 1100 m (B) apart, circles represent area covered with an effective broadcast radius of 550 m applied.

m and with vocalization and extensive movement at 550 m. The fifth pygmy-owl responded vocally at 550 m and with vocalization and movement at 250 m.

Discussion

It is possible that repeated sampling of the same individual on the same evening during 1996 may have influenced our results. However, because we maintained constant observation of the test pygmy-owl during testing and a 5-min period of silence was employed between broadcasts, we submit that the response distance recorded was a reasonable measure of the distance at which the response was elicited (see Methods, above). In addition, because we began testing at 700 m and moved closer to the targeted individual in 50-m increments, any error from repeated sampling would result in conservative response distance estimates.

Using the distance at which 100% vocal response was recorded (550 m), the effective coverage of areas formed by establishing survey points from 400–1400 m apart would range from 97.7–61.7%, respectively; broadcast overlap would range from 54.7–0.0%, respectively (Table 1). Our sample size may be considered too small to ascribe absolute response distance parameters. However, our data clearly show that broadcasted conspecific calls may elicit both movement toward the broadcast station and vocal response from pygmy-owls at a distance of 700 m. Consistent with Mays (1996), response distance information obtained from our study strongly suggests redundant sampling may occur along transects with survey points established ≤400 m apart. In addition, because several birds tested flew >500 m in response to broadcasted calls, our results question the likelihood that the mean radius of a pygmy-owl's territory is as small as Wauer et al. (1993) suggested, 297 m. Hence, Wauer et al. (1993) and Mays (1996) may have overestimated the pygmy-owl population size in Texas due to redundant detection of individuals and application of inappropriate territory size to extrapolate population estimates. Thus, biased data may have inadvertently altered the U.S. Fish and Wildlife Service's perception of a species in concern during the listing process.

Our data suggest that transects with survey points spaced from 400–600 m apart would potentially yield a high level of redundant sampling (>30% overlap). The current survey protocol authorized by

Table 1. Estimated percent coverage of rectangular area formed by multiplying observed response diameter (2 × response distance) of Ferruginous Pygmy-Owls in Texas by hypothetical distance (m) between broadcast stations Percent overlap depicts overlap of effective hemispherical response radii. Calculations follow Pythagorean and Archimedes theorems, as simulated in Figure 1.

	1100 m RESPONSE DIAMETER (550 m RESPONSE DISTANCE) 100% RESPONSE[b]		1200 m RESPONSE DIAMETER (600 m RESPONSE DISTANCE) 89% RESPONSE[b]		1400 m RESPONSE DIAMETER (700 m RESPONSE DISTANCE) 67% RESPONSE[b]	
DISTANCE[a]	COVERAGE	OVERLAP	COVERAGE	OVERLAP	COVERAGE	OVERLAP
400	97.7	54.7	98.1	58.3	100.0	64.1
500	96.4	44.2	96.8	48.6	97.9	55.5
600	94.8	34.2	95.7	39.0	96.9	47.2
700	92.8	24.8	94.6	29.7	95.7	39.1
800	90.3	16.4	92.1	21.8	94.4	31.4
900	87.1	9.3	89.6	14.4	92.7	24.3
1000	83.6	3.3	86.7	8.0	91.4	17.0
1100	78.5	0.0	83.2	2.9	88.5	11.6
1200	72.0	0.0	78.0	0.0	85.9	6.4
1300	66.5	0.0	72.5	0.0	82.7	2.3
1400	61.7	0.0	67.3	0.0	78.7	0.0

[a] Hypothetical distance between broadcast stations.

[b] Response frequency based on analysis of Ferruginous Pygmy-Owl response distances in Texas.

the U.S. Fish and Wildlife Service (2000) to determine presence or absence of pygmy-owls in urban and rural areas proposed for development requires a maximum distance of 150 m and 400 m between survey points, respectively. Based on our findings, this protocol should be an extremely effective means of determining presence of pygmy-owl within areas surveyed. However, due to the excessive overlap of broadcast radii, using U.S. Fish and Wildlife Service guidelines would undoubtedly not provide accurate census data. In rural areas, the U.S. Fish and Wildlife Service authorized a maximum distance of 500 m between survey points for studies conducted to ascertain the distribution of pygmy-owls in Arizona. A distance of 800 m is allowed if bionic ears or other listing-enhancement devices are used to detect respondents. Due to tree density and background noise (rustling leaves and branches), however, 500 m is maintained as the maximum distance between survey points in riparian areas, regardless of utilization of listening aids (U.S. Fish and Wildlife Service 2000). This too should effectively sample areas surveyed for presence or absence of pygmy-owls. However, the level of overlap and, hence, high potential for redundant sampling may render this protocol inaccurate for assessing abundance and density.

The initial cost of obtaining information regarding effective broadcast radius may be substantial, i.e., budgeting personnel and radiotelemetry equipment to conduct a response-distance study. However, the benefits of identifying the effective broadcast radius may transcend initial cost. For example, if we assume broadcast of conspecific calls will elicit 100% response from pygmy-owls at a distance of 550 m, increasing the distance between broadcast stations from 400–800 m would reduce effective broadcast coverage by 7.4%. However, it would also increase survey efficiency by 100%, and reduce overlap by 38.3%. Reducing overlapping broadcast radii would not only increase area covered, but should also reduce potential redundancies in sampling. This type of trade-off may be advantageous for surveying expansive areas with limited personnel resources. Antithetically, utilizing response-distance information, researchers may choose to canvas an area with overlapping radii to maximize detection of species of concern in areas proposed for development. To conclude, this type of research may aid species conservation by providing researchers basic information needed to develop survey protocols that maximize resource allocation with respect to survey intent and effectiveness. We suggest that the development of survey protocols should include empirical assessments of sampling effectiveness, both biologically and economically.

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